

Appendix D

**Type A Logging Data Used to Site Type B
Probe Clusters**

INTEROFFICE MEMORANDUM

Date: December 6, 2000

To: A. R. Baumer MS 3920 6-3238

From: J. W. Mandler MS 2114 6-0355
J. R. Giles MS 3950 6-4158

Subject: OPERABLE UNIT 7-13/14 DEPLETED URANIUM AND 741 STUDY AREA
PROBEHOLE RECOMMENDATIONS

Introduction and Objectives

This letter report recommends locations for installing additional Type A probeholes in the Depleted Uranium (DU) and 741 Sludge study areas within Pit 10 of the Subsurface Disposal Area (SDA). The recommended locations comprise probe clusters that will permit detailed evaluation of DU and 741 contamination source terms within localized areas. These recommendations are based on a detailed review of subcontractor-supplied downhole logging results along with limited additional logging data analysis.

The OU 7-13/14 Work Plan specifies the need to develop improved understanding of the long-term health and safety risk associated with uranium and neptunium waste at the SDA. The solubility of uranium and neptunium are important factors in developing realistic models of long-term risk. An initial exploration probing and logging campaign at Pit 10 was designed to identify uranium and neptunium bearing waste zones that can be used to study solubility issues.

The DU and 741 study areas were selected based on the expectation that these areas would contain uranium and neptunium-bearing waste (Figure 1). A suite of logging measurements including passive and active gamma-ray and neutron methods were performed in the exploration boreholes. Subcontractor-supplied logging data were reviewed to select locations for follow-up detailed studies. These detailed studies will be executed by installing probe clusters to facilitate sample collection, groundwater monitoring, and additional logging in a localized area. This report presents the recommended locations for the Type A probe clusters. Once installed, the cluster probes will be logged and the data will be used to quantify the uranium and neptunium source term within each localized area.

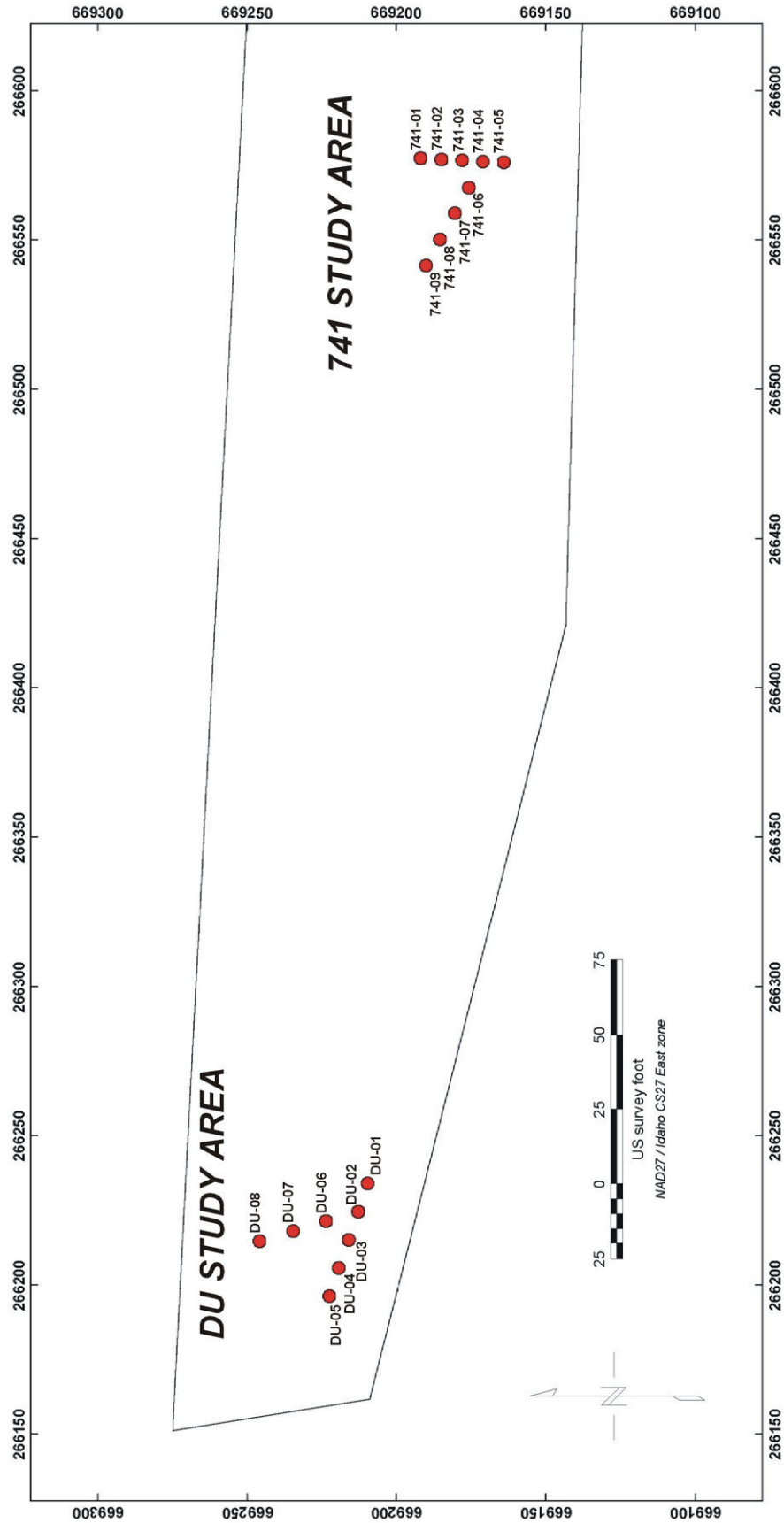


Figure 1. Map showing the DU and 741 study areas in relation to the Pit 10 boundary.

Analysis Methods

GTS results

The logging subcontractor conducted preliminary processing of the DU and 741 study area logging data. Their processing included automated spectral analysis of passive gamma-ray data to identify the presence of specific target contaminants including ^{235}U , ^{238}U , ^{239}Pu , ^{241}Am , and ^{237}Np ⁱ. After applying a standard calibration correction to convert net count rates to apparent radionuclide concentrations^j, summary results were compiled and delivered to the INEEL along with the raw spectral data.

The subcontractor summary results were organized into a comprehensive database to facilitate review. Tables 1 and 2 present the maximum apparent concentrations for the key contaminants in the two study areas. In addition, selected gamma-ray ratios were computed to help assess the nature of the uranium and neptunium waste mixtures (see Appendix C).

Table 1. Summary of maximum measured contamination levels for the DU study area.

Probe Identification	Total Depth	Max U238 (pCi/g)	Max U235 (pCi/g)	Max Pu239 (nCi/g)	Max Am241 (nCi/g)	Max Pa233 (pCi/g)
DU-01	14.3	91	1	-	-	-
DU-02	14.8	117	6	33	179	5
DU-03	14.5	1979	14	-	-	-
DU-04	14.0	-	-	-	128	-
DU-05	18.3	97	-	-	-	-
DU-06	18.5	45	-	-	-	-
DU-07	14.5	-	-	64	41	-
DU-08	18.4	469	18	4944	-	4881

Table 2. Summary of maximum measured contamination levels for the 741 study area.

Probe Identification	Total Depth	Max U238 (pCi/g)	Max U235 (pCi/g)	Max Pu239 (nCi/g)	Max Am241 (nCi/g)	Max Pa233 (pCi/g)
741_01	5.9	NOT LOGGED				
741_02	18.1	-	-	2084	13106	422
741_03	20.7	-	-	782	7938	244
741_04	24.3	-	-	1065	5509	172
741_05	6.2	NOT LOGGED				
741_06	18.0	681	84	1504	2386	72
741_07	6.3	NOT LOGGED				
741_08	21.8	-	-	8058	8874	311
741_09	14.3	267	28	-	-	-

i. ^{237}Np detection based on gamma-ray from short-lived daughter ^{233}Pa ; ^{238}U determined based on $^{234\text{m}}\text{Pa}$.

j. Subcontractor calibration corrections assume homogenous, isotropic, soil matrix.

Spectral analysis

In general, the raw spectral files for the DU and 741 study areas were not reviewed for this report since the primary recommendations are qualitative in nature. In a few cases spectra were reviewed to identify secondary gamma-rays as a means to clarify subcontractor interpretations based on primary gamma-rays.

Cluster Probe Recommendations

Cluster probe recommendations are based on a conceptual model of uranium and neptunium target distributions as herein described. Nuclear logging methods for uranium and neptunium have a relatively limited volume of investigation (approx. 0 – 1 ft). The logging tool may pass through or alongside one or more source volumes during logging operations in any probe. The logging instruments will record increased gamma-ray activity only if some part of a source volume occurs within the volume of investigation of the logging tool. For purposes of this interpretation, we assume that the measured logging response at any given depth is influenced by a single source distribution having a total volume less than or equal to the volume of a 55-gal drum (approx. 9 ft³). Thus, in the absence of more complex analysis, each gamma-ray peak recorded in the logging data is considered to reflect the presence of a single waste drum that may be used as a target for cluster probe study.

The recommended cluster probe geometry consists of six equally spaced probes forming a ring around the probe of interest (see Figure 2). The cluster probe pattern has a footprint of 3 x 3 ft, and is well suited to intersect and surround a target volume of 9 ft³. In addition, the spacing between probes is 1.5 ft, so that the volume of investigation for adjacent probes will intersect slightly.

DU Area

The primary recommended cluster probe target in the DU study area occurs in probehole DU-03 at a depth of 9.0 ft. This zone has the following attributes:

- Both ²³⁸U and ²³⁵U observed in high concentrations compared with other DU area probeholes
- ²³⁵U/²³⁸U ratios consistent with depleted uranium^k
- No other intermixed contamination observed
- Reduced contamination level for several ft below high contamination zone provides convenient conditions for leachate collection and migration studies.

The secondary recommended cluster probe target in the DU study area occurs in probehole DU-08 at a depth of 12.5 ft. This zone has the following attributes:

- Both ²³⁸U and ²³⁵U observed in high concentrations compared with other DU Area probeholes
- ²³⁵U/²³⁸U ratios consistent with natural uranium
- Pu/Am/Np occurs within same depth zone as ²³⁵U/²³⁸U

k. ²³⁵U/²³⁸U ratios also depend on the position of the source relative to the logging tool, since ²³⁵U and ²³⁸U gamma-rays are attenuated differently in soil media

- $^{235}\text{U}/^{238}\text{U}$ occurs near bottom of hole.

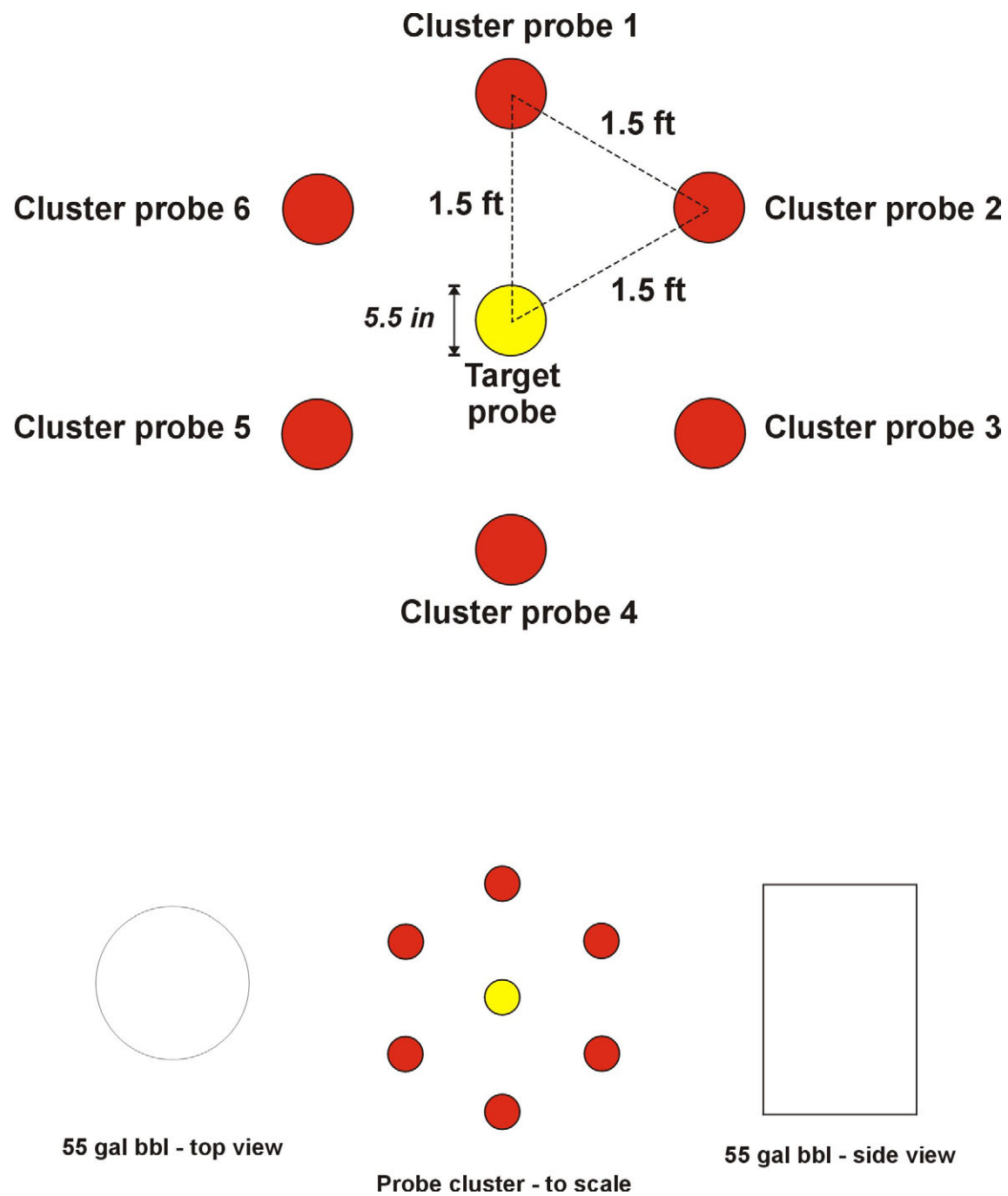


Figure 2. Probe cluster geometry with comparison to 55 gal drum size.

Table 3 gives coordinates for the primary and secondary DU area cluster probes.

741 Area

The primary recommended cluster probe target in the 741 study area occurs in probehole 741-08 at a depth of 8.0 ft. This zone has the following attributes:

- Pu/Am/Np observed in high concentrations compared with other 741 Area probeholes
- Single, narrow Pu/Am/Np contamination zone with no other intermixed contamination observed
- Zone shows significant ^{237}Np enrichment relative to the amount expected from the decay of pure ^{241}Am
- Reduced contamination level for 10 ft below high contamination zone provides convenient conditions for leachate collection and migration studies.

The secondary recommended cluster probe target in the 741 study area occurs in probehole 741-02 at a depth of 10.5 to 11.5 ft. This zone has the following attributes:

- Pu/Am/Np observed in high concentrations compared with other 741 area probeholes
- Single, broad Pu/Am/Np contamination zone with no other intermixed contamination observed
- Zone shows significant ^{237}Np enrichment relative to the amount expected from the decay of pure ^{241}Am
- Reduced contamination level for 5 ft below high contamination zone provides convenient conditions for leachate collection and migration studies

Table 4 gives coordinates for the primary and secondary 741 area cluster probes based on a 1.5 ft probe spacing.

Table 4. Coordinates for recommended cluster probe locations.

Well ID	Easting ^a	Northing ^a
DU-03-C1	266215.2	669217.6
DU-03-C2	266216.5	669216.9
DU-03-C3	266216.5	669215.4
DU-03-C4	266215.2	669214.6
DU-03-C5	266213.9	669215.4
DU-03-C6	266213.9	669216.9
DU-08-C1	266214.8	669247.3
DU-08-C2	266216.1	669246.6
DU-08-C3	266216.1	669245.1
DU-08-C4	266214.8	669244.3
DU-08-C5	266213.5	669245.1
DU-08-C6	266213.5	669246.6
741-08-C1	266550.2	669186.9

Table 4. (continued).

Well ID	Easting ^a	Northing ^a
741-08-C2	266551.5	669186.2
741-08-C3	266551.5	669184.7
741-08-C4	266550.2	669183.9
741-08-C5	266548.9	669184.7
741-08-C6	266548.9	669186.2
741-02-C1	266577.1	669186.5
741-02-C2	266578.4	669185.8
741-02-C3	266578.4	669184.3
741-02-C4	266577.1	669183.5
741-02-C5	266575.8	669184.3
741-02-C6	266575.8	669185.8

a. Idaho State Plane, East Zone, NAD 27

Azimuthal uncertainty

The existing logging measurements for the DU and 741 study areas contain no information concerning the azimuthal position of the source around the probehole. The recommended cluster probe geometry is designed to accommodate any of the possible locations of the source zone with respect to the target probe. In the event that azimuthal information can be successfully collected within the target zone, and that these data indicate a clear azimuthal position of the contamination source the number of cluster probes may be reduced, and located in the optimal azimuthal direction.

Other Observations

This section documents some additional observations noted during review of the subcontractor data summary. Further details concerning these observations may be found in Appendices A and B.

²³⁷Np and ²⁴¹Am enrichment

Table 5 shows a comparison between expected and observed Pu/Am/Np ratios where the expected values are based on 30-year decay of weapons grade plutonium^l. The observed Am and Np values indicate enrichment relative to Pu for this specific decay scenario. This general condition of Am and Np enrichment was observed throughout the DU and 741 study areas.

Table 5. Comparison of expected and observed Pu/Am/Np activity ratios.

Ratio	Weapons-grade Pu	Observed
²³⁹ Pu/ ²⁴¹ Am	6.7	0.1; 1
²⁴¹ Am/ ²³³ Pa	100,000	33,000
²³⁹ Pu/ ²³³ Pa	1,100,000	2000; 30,000

l. All ²⁴¹Am derived from decay of ²⁴¹Pu, and all ²³⁷Np derived from decay of ²⁴¹Am.

Elevated ²³²Th levels

Apparent elevated natural thorium concentrations were observed in several of the probeholes in the 741 Sludge study area, indicating a potential source of Th-228 that was not identified in the interim baseline risk assessment. Probehole 741-2 exhibits the highest observed concentrations of natural thorium at a depth of 12.0 ft and a concentration of 58.41 pCi/g. The elevated thorium in probehole 741-2 spans a depth range from approximately 8.0 ft to 17.0 ft. The elevated thorium is also present in probeholes 741-3, 741-6, 741-8, DU-7 and DU-8, however, the elevated thorium in DU-7 has been determined to be natural thorium (Th-232). It is important to note here that the mean background value for natural thorium in INEEL soils is 1.25 pCi/g (Rood et al. 1996).

Enriched uranium

Enriched, or highly enriched uranium was identified in probeholes 741-6 and 741-9. These zones were identified at the bottoms of the probeholes, separate from any Am-241 or Np-237. Natural uranium or enriched uranium was located far from the probe (see J.W. Mandler's observations and comments).

¹³⁷Cs

Cesium-137 was identified in probehole 741-4 at a depth interval from 13.0 to 20.0 ft, with a maximum concentration of 139.4 pCi/g at a depth of 16.5 ft. It was determined that this is a true source of Cs-137, as discussed in J.W. Mandler's observations.

Summary

This letter report and appendices represent what is to be considered a minimal data analysis. Based on this analysis, a Type A cluster probe configuration is proposed for each study area of interest including DU-3, DU-8, 741-8 and 741-2. Upon installation of the cluster probes, it is recommended that both the conventional GTS logs and the azimuthal logs should be completed followed by a more detailed data analysis than what was presented here. This is required for the process of estimating the source term around the selected probeholes, which will support the evaluation of uranium and neptunium solubility.

**Summary of DU and 741 Area Azimuthal Logging
Logging data through 5/23/01**

N.E. Josten
6/1/01

Summary of DU and 741 Area Azimuthal Logging Logging data through 5/23/01

N.E. Josten
6/1/01

Introduction

The OU7-13/14 project conducted azimuthal gamma-ray logging in selected probes within the DU, 741 and 743 study areas as a means to investigate the spatial distribution of subsurface radionuclides. Twelve probes were selected for the azimuthal surveys based on existing geophysical logging data. These probes were selected because they contained high levels of either ^{238}U or ^{237}Np (see Table 1).

Table 1. Probeholes selected for azimuthal logging.

Probehole	Depth (ft)	Radionuclide	Max cps ^a
DU-10	7.5	^{238}U	3253
743-08	22.5	^{238}U	220894
DU-16	11.5	^{238}U	6604
DU-14	13.5	^{238}U	17300
DU-03	8.0	^{238}U	1979
DU-15	11.5	^{238}U	1947
DU-08	14.5	$^{237}\text{Np}^b$	4944
741-08	8.0	^{237}Np	316
741-02	11.5	^{237}Np	428
741-04	9.5	^{237}Np	172
741-03	9.5	^{237}Np	244
743-12	15.5	^{237}Np	275

a. as observed by standard gamma-ray logging

b. ^{237}Np indicated by ^{233}Pa daughter

Azimuthal logging was conducted by GTS Duratek during May, 2001 and preliminary results were delivered to the INEEL on May 31, 2001. Figure 1 shows the cover letter included with the data delivery.

Azimuthal logs were analyzed to choose probes for follow up studies of ^{238}U or ^{237}Np leaching and migration. Azimuthal data were used to indicate the position of ^{238}U or ^{237}Np relative to the probehole so that lysimeters could be installed to collect leachate samples.

Results

For each probe, Table 2 lists detected radionuclides and gives the azimuth of the observed maximum count rate for each. Azimuth is measured with respect to a north arrow marked on the probe casing. Table 2 also gives the approximate maximum count rates and two general qualifiers. The first qualifier describes the statistical significance of the direction indication and the second qualifier describes the narrowness of the direction indication (i.e. "good" indicates a highly directional source and "poor" indicates a broadly directional source).

The Table 2 data were used to determine the position and target depth for Type B probes. These data may also be used to choose locations for additional Type A probes in the event that it becomes necessary to model the radionuclide source distribution in detail.

Table 2. Azimuthal data summary.

Probe	Depth (ft)	Nuclide @ azimuth	Max cps	Statistics	Direction
DU-10	7.5	^{238}U @ 190°	4	Good	Good
743-08	22.5	^{238}U @ 200°	120	Good	Poor
		^{235}U @ NA	2.5	Poor	Poor
DU-16	11.5	^{238}U @ 135°	2.5	Fair	Good
		^{238}U @ 270°	1.8	Good	Good
		2614 keV @ 235°	3.3	Good	Good
DU-16	13.5	^{238}U @ 130°	5.5	Good	Good
DU-14	8.0	^{238}U @ 65°	21	Good	Good
		^{238}U @ 200°	11	Good	Fair
DU-14	10.0	^{238}U @ 190°	1.1	Fair	Good
		^{239}Pu @ 45°	0.7	Fair	Good
DU-03	8.5	^{238}U @ 140°	1.4	Fair	Fair
DU-15	13.5	^{239}Pu @ 315°	75	Good	Good
DU-15	15.5	^{238}U @ 35°	1.7	Good	Good
DU-08	12.5	^{238}U @ 350°	0.5	Good	Good
DU-08	14.5	^{233}Pa @ 190°	14	Good	Good
741-08	8.0	^{233}Pa @ 125°	2.5	Fair	Good
		^{241}Am @ 115°	3.5	Fair	Fair
		^{239}Pu @ NA	2.8	Good	Poor
741-02	11.5	^{233}Pa @ 85°	5.5	Good	Fair
		^{241}Am @ 80°	6.2	Good	Fair
		^{239}Pu @ 85°	0.6	Poor	Good
		583 keV @ 80°	0.8	Fair	Fair
741-04	9.5	^{233}Pa @ 200°	1.4	Good	Poor
		^{241}Am @ 205°	2.0	Good	Poor
		^{239}Pu @ 180°	0.4	Poor	Good
741-03	9.5	^{233}Pa @ 35°	2.4	Good	Fair
		^{241}Am @ 35°	3.3	Good	Fair
743-12	15.5	^{239}Pu @ 180°	29	Good	Poor

May 29, 2001

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From: Jim Meisner
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Subject: Geophysical Log Data from RWMC Pit 5 Boreholes and P9-20. 743-08

Enclosed you will find preliminary results of the May 13-23, 2001 logging campaign with four geophysical log types (azimuth, neutron-moisture, passive-neutron, and neutron-gamma). The azimuth surveys were acquired at selected depths in predetermined probe holes. The neutron-moisture, passive-neutron and a partial set of the neutron-gamma surveys were acquired in the RWMC Pit 5 probe holes and the six delineation probe holes installed around P9-20 and 743-08. The remaining surveys (i.e. passive-gamma and neutron-gamma) will be collected on the next logging campaign.

The azimuth survey results are presented as both a polar and an x-y cartesian plot of azimuth direction versus activity. The cartesian plot count rate activity (y-axis in counts per second) includes error bars at two sigma level (95% confidence interval). The total gamma activity plot is included for consistency with previous azimuth survey results. Also, note that the net gamma ray count rates are now better with the improved azimuth shield. Therefore, future azimuth survey plot results will feature the net gamma ray count rates and will not include the total gamma plots.

The north direction was not marked on some of the casing for the azimuth survey. In these cases, the logger estimated north and placed a mark on the casing for the azimuth survey. A comment is included on the corresponding azimuth survey plots.

The azimuth survey results for DU-08 at 14.5 ft, 312 keV (Pa-233) are different than expected. The 312 keV gamma ray attenuation through the shield is excessive. Other physical processes are occurring. No other azimuth surveys exhibit this condition. Investigation to identify the cause is recommended.

An Excel file is included that identifies the borehole numbers, depth, and initial date each probe type was run for the new probe holes being logged.

The results include survey plots (hard copy) and electronic data files:

1. Plots of neutron moisture and passive neutron are presented as 2 log tracks on one page for each borehole. The background neutron activity has been subtracted from the moisture results.
2. CD-ROM disk contains:
 - Raw survey data (Ortec -.CHN files compressed into WinZip format),
 - Preliminary survey results in Microsoft Excel spread sheet format,
 - Graphical presentation of survey data (sigma plot format and window-meta-file format), and
 - Microsoft Word document file of data plots.

Figure 1. GTS Duratek data submittal cover letter.

**Summary of DU and 743 Study Area logging results through
2/5, w/ emphasis on new logging data received 1/29/01**

N. E. Josten
2/6/01

**Summary of DU and 743 Study Area logging results through 2/5,
w/ emphasis on new logging data received 1/29/01**

N. E. Josten
2/6/01

DU Area

Logging status

- ✓ 9 new probes (DU-09 through DU-17)
- ✓ gamma logs – 9/9 complete
- ✓ moisture logs – 9/9 complete
- ✓ neutron logs – 9/9 complete
- ✓ n-gamma logs – 3/9 complete

Results

The table below gives maximum detected levels of key target contaminants for all DU Area probes. NL indicates “not logged.” Blank cells indicate non-detects.

Well_ID	Cl_1165 cps	Cl_6111 cps	U235_186 pCi/g	U238_1001 pCi/g	Pu239_414 nCi/g	Am241_662 nCi/g	Pa233_312 pCi/g
DU-01	23	10	1	91			
DU-02	5	3	6	117	33	179	5
DU-03	20	8	14	1979			
DU-04						128	
DU-05	2	1		97			
DU-06	22	10		45			0
DU-07	4	3			64	41	
DU-08	21	9	18	469	4944		4881 ^a
DU-09	21	8					
DU-10	10	4		3253			
DU-11	11	4	11	1139	776	58	1
DU-12	NL	NL	2	36	12		2
DU-13	NL	NL	73	164	804	63	4
DU-14	NL	NL		17300	339	33	
DU-15	NL	NL	17	1947	48699	4878	164
DU-16	NL	NL	9	6604			
DU-17	NL	NL	2	1514	446	46	4

a. This apparently anomalous value for Pa-233 has been brought to the attention of GTS

U-238 was more widespread in the new probes than in the original eight probes. Three of the new probes had higher apparent U-238 concentrations than previously observed in the DU study area. DU-14 had an apparent U-238 concentration of 17,300 pCi/g (compared to a previous high in DU-03 of 1979 pCi/g). Based on these new measurements, we may wish to reconsider our Type B probe targets. (See Figure 1.)

U-235 levels observed in the new probes are comparable to those observed in the original eight probes. DU-13 had an apparent U-235 concentration of 73 pCi/g (compared to a previous high in DU-08 of

18 pCi/g). As before, U235 is often not detected above the noise level even when U238 is prominent. (See Figure 2.)

U-235:U-238 concentration ratios, uncorrected for differential attenuation, show two trends: U235:U238 \approx 0.008:1 and U235:U238 \approx 0.04:1. These ratios are similar to those observed and reported for the original 8 probes, suggesting that we are observing similar waste mixtures. (See Figure 3.)

Pu/Am/Np are observed in various combinations throughout the DU study area, with higher relative amounts of Pu compared to other areas of Pits 4, 9 and 10. Probe DU-15 shows an apparent Pu-239 concentration just under 50,000 nCi/g, or about 25% of the level observed in P9-20. The predominant Am:Pu concentration ratio is 0.12:1, compared with 10.8:1 and 1:1 observed in the 741 study area. As elsewhere in Pits 4 and 10, Am:Pa ratios show a consistent value near 32,000:1. The Am:Pa ratio suggests an excess of Np relative to the amount expected from pure Am decay, but nonetheless in constant proportion to Am. (See Figure 3.)

Locations for probes DU-09 through DU-17 were chosen partly on the basis of surface geophysical data to give a comparison between probes positioned at the peak of geophysical anomalies versus probes located on the flanks of geophysical anomalies. The logging data show that radionuclides were detected in all locations and that variations in apparent radionuclide concentration are unrelated to the geophysical data (Figure 4).

743 Area

Logging status

- ✓ 11 new probes (743-32 through 743-42)
- ✓ gamma logs – 9/11 complete
- ✓ moisture logs – 2/11 complete
- ✓ neutron logs – 2/11 complete
- ✓ n-gamma logs – 10/11 complete

Results

The table below gives maximum detected levels of key target contaminants for all 743 Area probes. NL indicates “not logged.” Blank cells indicate non-detects.

Well_ID	Cl_1165 cps	Cl_6111 cps	U235_186 pCi/g	U238_1001 pCi/g	Pu239_414 nCi/g	Am241_662 nCi/g	Pa233_312 pCi/g	2614keV cps
743-01	15	6			70			
743-02	27	11	4		206	47		
743-03	35	15			137			
743-04	30	11			1447	3251		5
743-05	27	12		103	1630	10467		23
743-06	30	13			2168	272	9	2
743-07	22	10	19	1582	280	545	14	24
743-08	29	11	345	220894	9005	1857	58	65
743-09	27	12		330	1547	1242	37	5
743-10	32	12	14	714	963	477	14	3
743-11	23	9	20	1064	5958	2048	49	18
743-12	20	10	63		72259	8160	275	
743-13	26	12	7	114	1055	231	5	7
743-14	27	11	35	50	67	120	1	1

Well_ID	Cl_1165 cps	Cl_6111 cps	U235_186 pCi/g	U238_1001 pCi/g	Pu239_414 nCi/g	Am241_662 nCi/g	Pa233_312 pCi/g	2614keV cps
743-15	22	8	21		1105	106		
743-16	17	8			1098	162		
743-17	9	4		177	292	89	1	2
743-18	5	2			135			1
743-19								
743-20	4	2		737	602	143		
743-21					763	102		
743-22	2	1			4355	341		
743-23								
743-24	2	1			3531	466	12	
743-25								
743-32	3	1				34		
743-33	0		0					
743-34								
743-35	1	1	NL	NL	NL	NL	NL	NL
743-36	17	9	108	840	13887	1466	32	4
743-37	24	9			90			1374
743-38	16	8			117			
743-39	9	4	NL	NL	NL	NL	NL	NL
743-40	28	12	1	11	98			
743-41	7	4	7			29		
743-42	NL	NL	10					1

New probes show that chlorine concentrations diminish toward the northern Pit 4 boundary. The ISV probes (743-34 through 743-42) show some high chlorine levels comparable to transect probes, and some low (or non-detect) chlorine levels due presumably to the northern limit of waste. Both the 1165 keV and 6111 keV chlorine lines present the same general picture of chlorine distribution (see Figure 5).

U-238 and U-235 are observed throughout the central portion of the main transect (743-05 through 743-17). Probe 743-08 show an apparent U-238 concentration of 220,894 pCi/g, which is an order of magnitude higher than the previous highest U-238 probe (DU-14) and two orders of magnitude greater than the highest levels observed elsewhere in the 743 area.

Pu/Am/Np are observed in various combinations throughout the 743 study area. Probe 743-12 shows an apparent Pu-239 concentration of 72,259 nCi/g, about 33% of the level observed in P9-20.

The logging subcontractor noted elevated 2614 keV gamma ray counts in many of the central and northern transect probes. Elevated 583 keV and 511 keV counts were also reported. According to GTS, these gamma-rays are associated with Tl-208, and they have traced activity from Tl-208 parents up through Pb-212 but no further. Also, GTS reports several other unidentified gamma-rays in probes having Tl-208 gammas. The significance of these observations is not presently understood. Note that all observed 2614 gamma-ray levels are in the range of 1 – 65 cps, except for probe 743-37, which had 1374 cps.

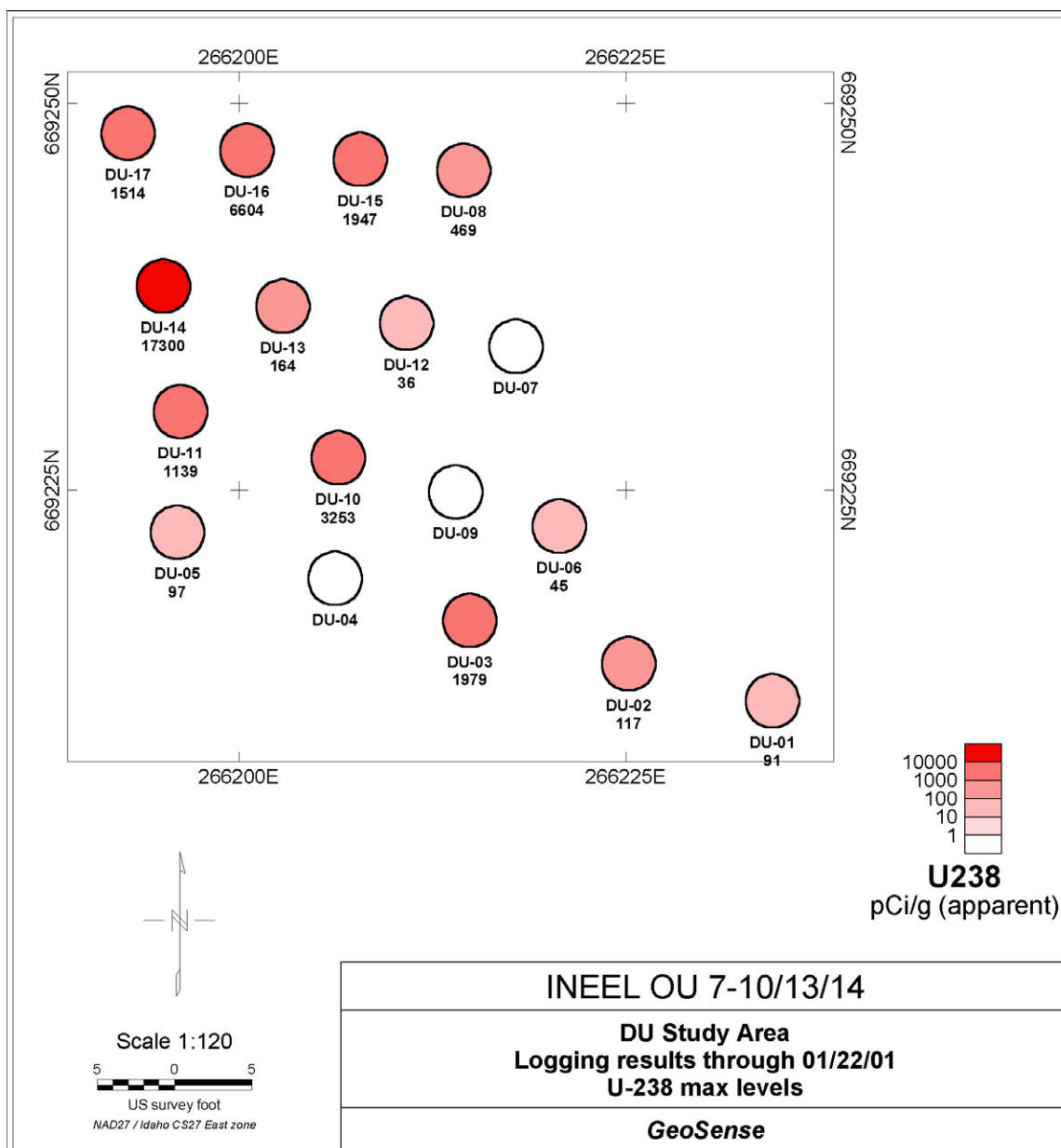


Figure 1. U-238 apparent concentrations.

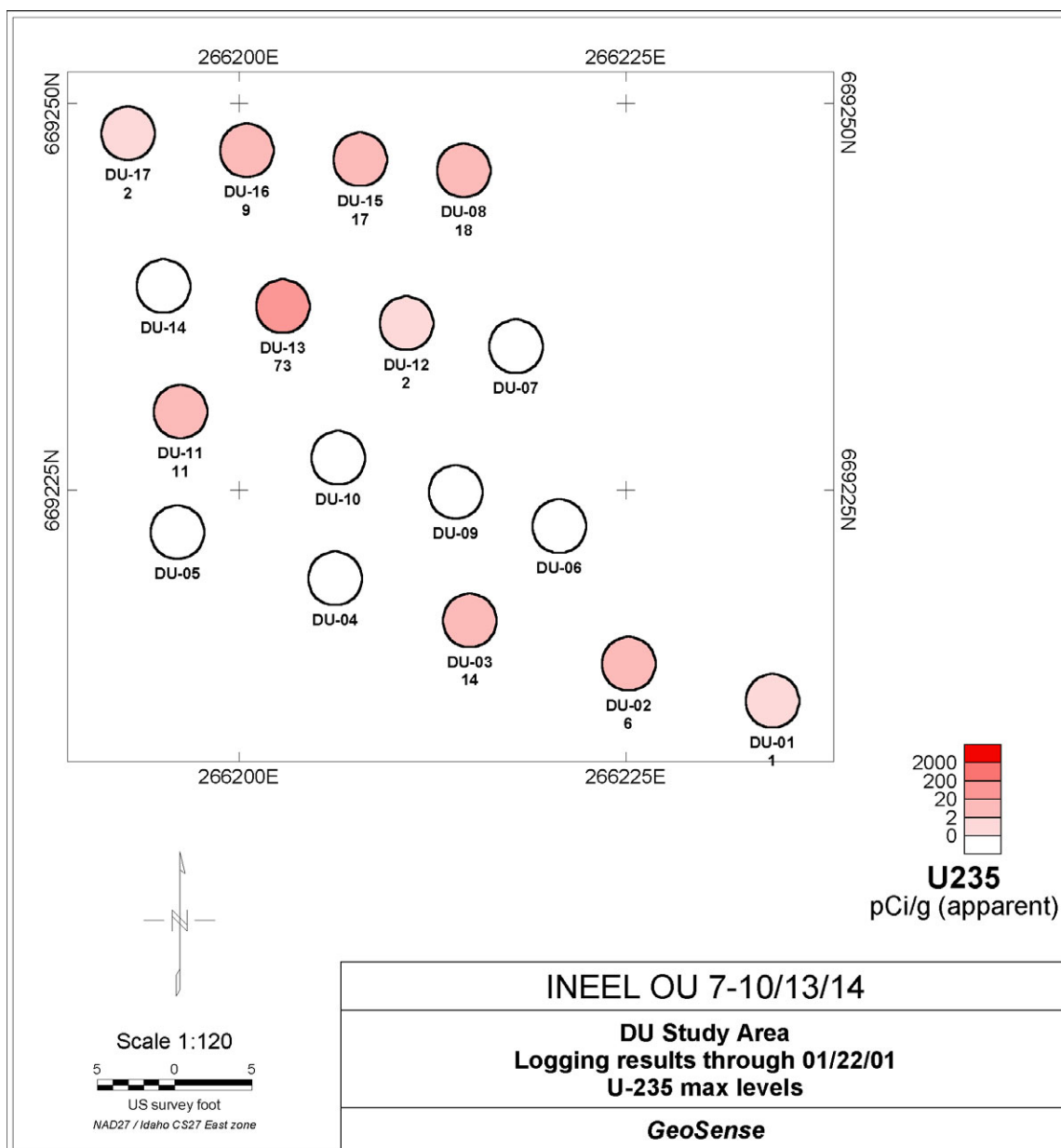


Figure 2. U-235 apparent concentrations.

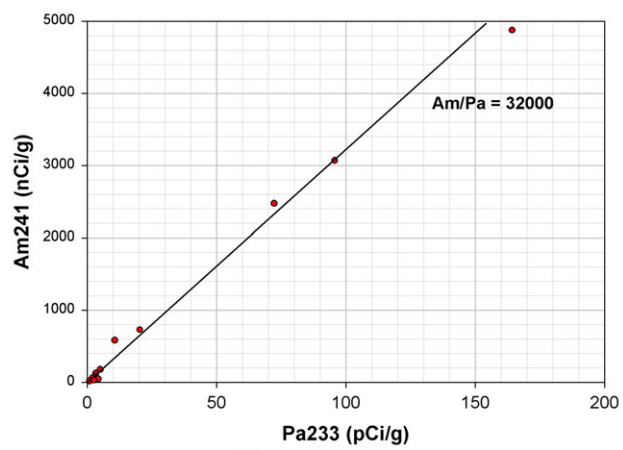
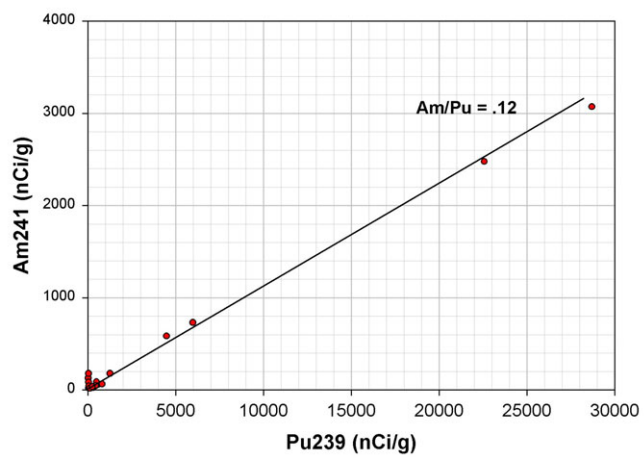
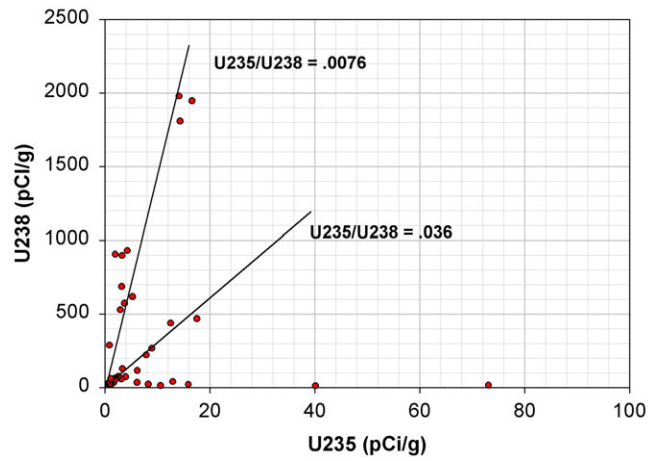


Figure 3. Apparent concentration ratios.

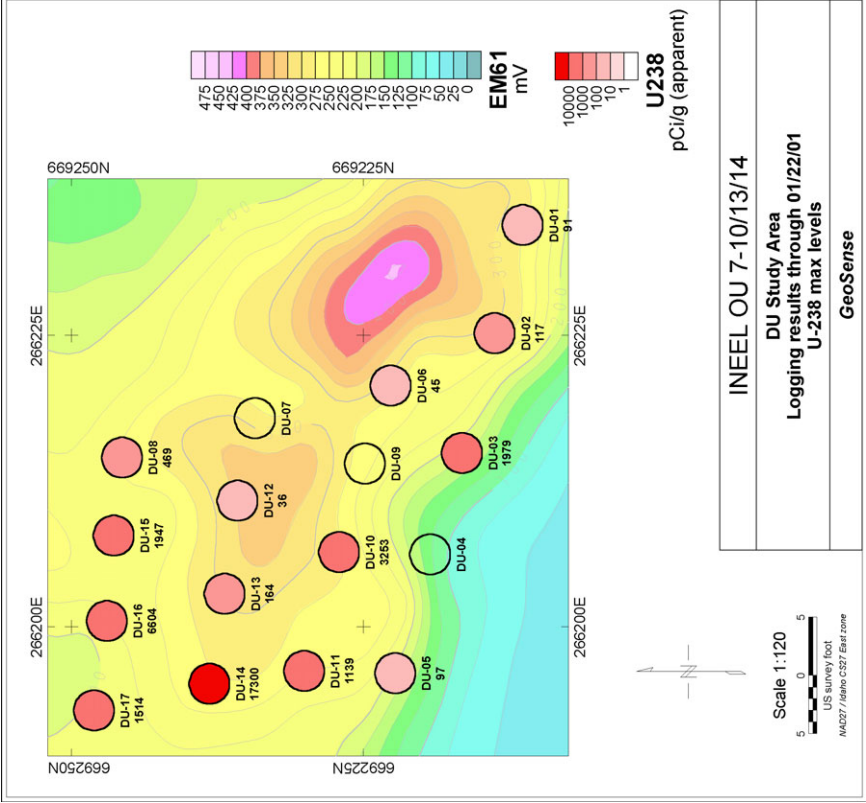
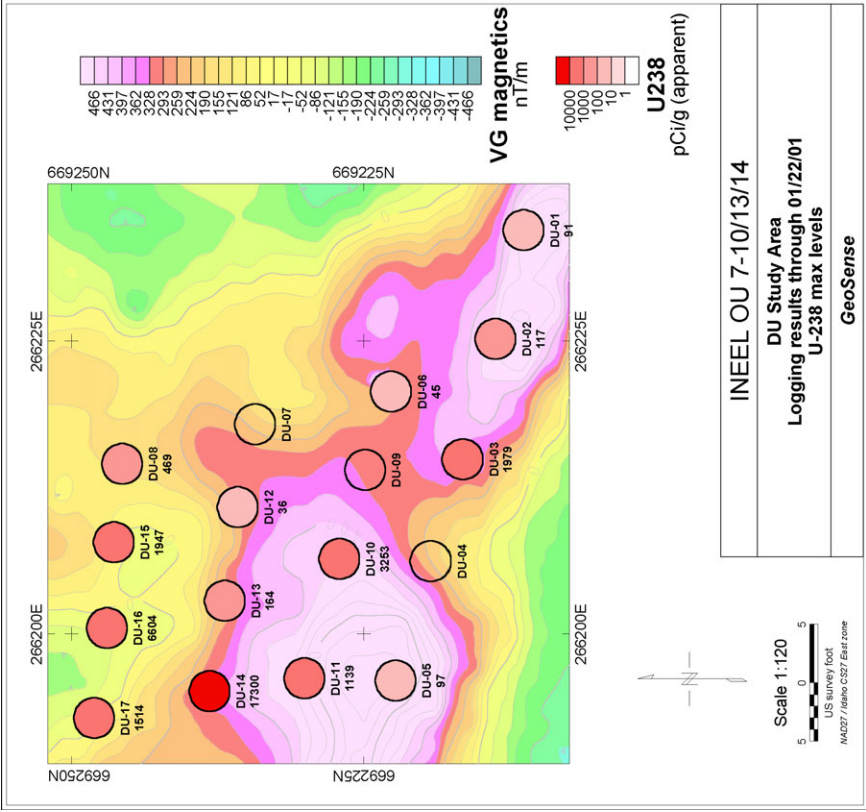


Figure 4. Apparent U-238 concentrations compared with surface geophysics.

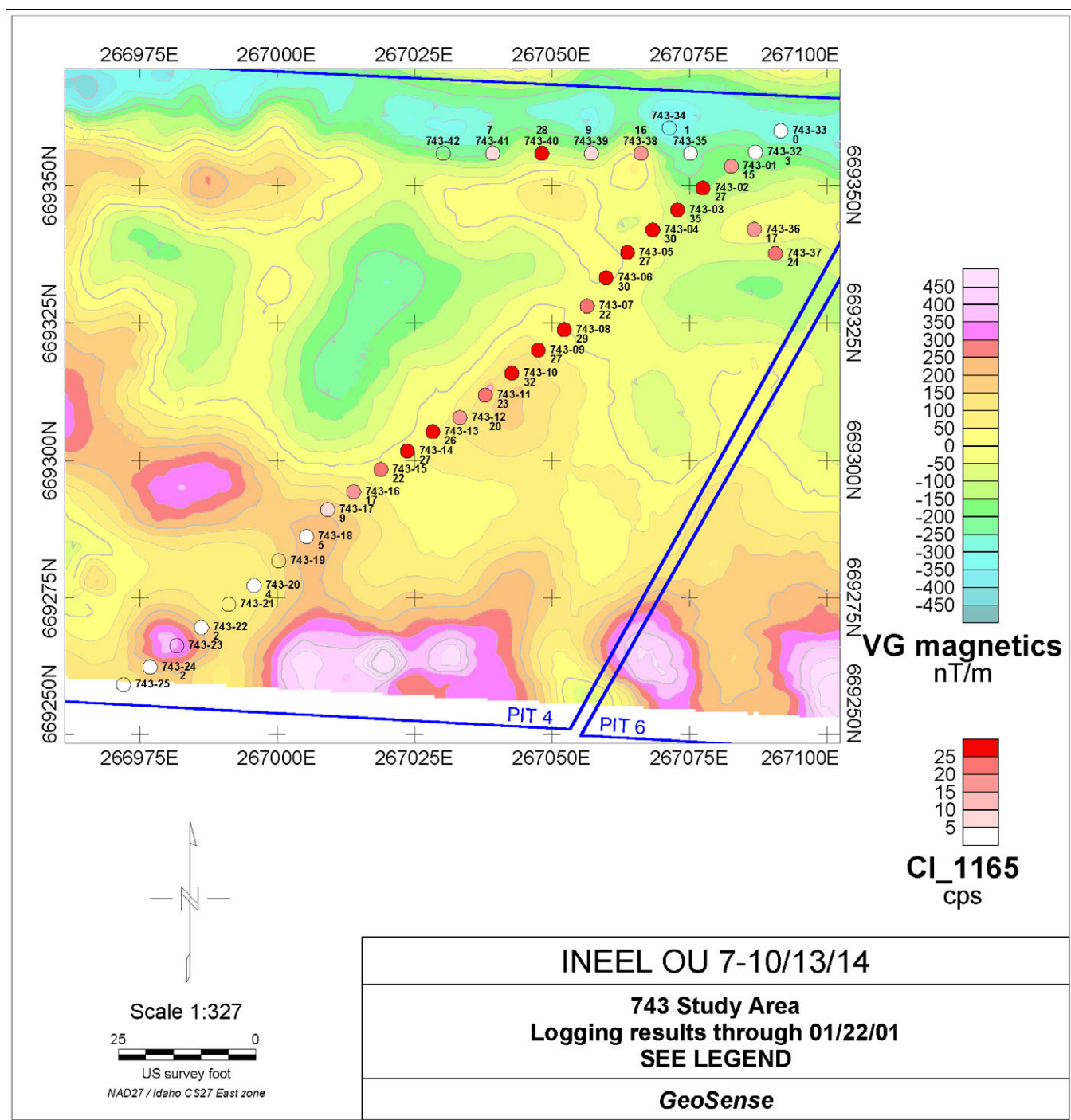


Figure 5. CI_1165 keV logging results compared with surface geophysics.

Appendix A

J. Mandler notes on evaluation of DU and 741 Study Area subcontractor data

Observations and Comments
Logging Data for Pits 4 & 10 DU and 741 Study Areas
J.W. Mandler
Updated 12/05/00

DU-1

Elevated levels of ^{238}U (up to 90 pCi/g) were seen by GTS Duratek in the 4.5-10.5 ft region. ^{235}U was seen at 9.5 and 10 ft, at concentrations of 1.3 and 1.2 pCi/g, respectively.

$^{235}\text{U}/^{238}\text{U}$ activity ratios (at the 9.5-10 ft level, the only locations where ^{235}U was detected) ranged from 0.03 to 0.05. Since the $^{235}\text{U}/^{238}\text{U}$ activity ratio for natural uranium is 0.047, the measured activity ratios indicate that the uranium is either natural or enriched, but located far from the probe (i.e., is highly attenuated).

^{232}Th levels are depressed (by up to slightly more than a factor of 2) in the 6.5-10 ft region, essentially the region where the elevated levels of ^{238}U were seen.

^{40}K levels are depressed (up to more than a factor of 2 below normal values) in the 6.5-10 ft region, essentially the region where the elevated levels of ^{238}U were seen.

The x2 depression of the ^{232}Th and ^{40}K concentrations in the 6.5-10 ft region indicates the presence of waste, which displaced some of the soil.

GTS Duratek found no ^{241}Am , ^{239}Pu , ^{233}Pa .

DU-2

Elevated levels of ^{238}U (up to 117 pCi/g at the 7.5 ft level) were seen in the 5.5-10 ft level and at the 4 ft level. ^{235}U was seen at 7.5 and 8 ft, concentrations of 6.2 and 3.9 pCi/g, respectively.

$^{235}\text{U}/^{238}\text{U}$ ratios ranged from 0.02 to 0.05. This indicates that the uranium is either natural or enriched, but located far from the probe (i.e., is highly attenuated).

^{239}Pu was seen in the 7-8 ft region (peaking at slightly over 30 nCi/g in the 7-7.5 ft region). If GTS Duratek used only the 414 keV gamma ray to measure ^{239}Pu , then the reported ^{239}Pu concentrations will be biased high by about 10-15% due to the 416 keV gamma ray from ^{233}Pa .

GTS Duratek found ^{241}Am at the 0.5 ft level, in the 2.5-3 ft region (7-10 nCi/g). At the 4 ft level (10 nCi/g), in the 6-9 ft region (9-179 nCi/g), and at the 10 ft level (11 nCi/g). It peaked in the 7-8 ft region (reaching a peak of 179 nCi/g at the 7.5 ft level).

At the 7.5 ft level, the $^{241}\text{Am}/^{237}\text{Np}$ ratio was 3.6E04. This is lower by about a factor of 3 than it would be if all the ^{237}Np came from the decay of ^{241}Am and lower by almost a factor of 5 than it would be if all the ^{237}Np came from the decay of ^{241}Pu through ^{241}Am .

Using the GTS Duratek reported ^{239}Pu concentrations, the $^{239}\text{Pu}/^{241}\text{Am}$ ratios were 0.37, 0.18, and 0.12 at the 7, 7.5, and 8 ft levels, respectively. These values are much lower than the value of 6.7 which is what would be expected from 30-year-old weapons-grade material in which all the ^{241}Am came from the decay of ^{241}Pu . The ratios indicate that 94-98% of the ^{241}Am that is seen is a source of separated ^{241}Am and not from the decay of ^{241}Pu . If our corrected ^{239}Pu concentrations are used, then the $^{239}\text{Pu}/^{241}\text{Am}$ ratios would

be slightly lower and the fraction of the ^{241}Am coming from the decay of ^{241}Pu correspondingly lower also.

^{233}Pa was seen in the 7-8 ft region (peaking at 5 pCi/g at 7.5 ft level). Its activity tracked the ^{239}Pu activity, so they are probably associated.

Using the GTS Duratek reported ^{239}Pu concentrations, the $^{239}\text{Pu}/^{233}\text{Pa}$ ratios were 1.0E04, 6.6E03, and 4.8E03 at the 7, 7.5, and 8 ft levels. These ratios are much smaller than the ratio expected (i.e., 1.107E06) from 30-year-old weapons-grade plutonium. The corresponding $^{241}\text{Am}/^{233}\text{Pa}$ ratios were 2.8E04, 3.6E04, and 3.8E04. These ratios are lower than the ratio expected (i.e., 1.00E05) from 30 year-old ^{241}Am . The ratios indicate that less than 1% of the ^{237}Np came from the decay of ^{241}Pu and that 62-72% of the ^{237}Np did not come from the decay of ^{241}Am .

The conclusion is that there is both added ^{241}Am and added ^{237}Np . The ratios indicate that less than 1% of the ^{237}Np came from the decay of ^{241}Pu and that only 28-38% came from the decay of ^{241}Am . Therefore, most of the ^{237}Np (i.e., 60-70%) is from additional, separated ^{237}Np .

^{40}K seemed about normal at all levels.

^{232}Th activity was elevated (by up to about a factor of 6) in the 6.5-9 ft region (peaking at 8 pCi/g at 7.5 ft level). The gamma rays upon which this identification is based are the 583 keV and 2614 keV gamma rays from the decay of ^{208}Tl (a progeny of ^{232}Th). Review of the spectrum obtained at 7.5 ft (the level where the reported ^{232}Th concentration is maximum) indicated no 911 keV or 969 keV gamma rays. These gamma rays (from the decay of ^{228}Ac) should be present if the actual parent radionuclide is ^{232}Th . A review of spectra obtained from levels where the reported ^{232}Th concentration is normal (i.e., is due to natural ^{232}Th in the soil) indicates a normal intensity 911 keV and 969 keV gamma-ray peaks. The absence of the 911 keV and 969 keV gamma rays indicates that the parent radionuclide of most of the ^{208}Tl actually is ^{228}Th rather than ^{232}Th . The conclusion is that there is a source of separated ^{228}Th in the waste. Since ^{228}Th has a half-life of 1.9131 years, there had to be a relatively large amount of ^{228}Th in the waste when it was buried. After 30 years, the fraction of ^{228}Th left would be 1.8E-05. Therefore, 8 pCi/g today would have been 445 nCi 30 years ago.

Review of the spectrum obtained at the 7.5 ft level, where the reported ^{241}Am concentration peaked, indicated a 583 keV peak, probably from the (alpha,n) reaction on fluorine by alphas from ^{241}Am , and a very small 1274 keV peak, probably from the (alpha,p) reaction of fluorine by alphas from ^{241}Am .

DU-3

Elevated levels (up to 1979 and 1810 pCi/g at 8.5 and 9 ft, respectively) of ^{238}U were seen in the 5.5-12.5 ft region. ^{235}U was seen in the 7-9.5 ft region (peaking at 14 pCi/g at 8.5-9 ft).

$^{235}\text{U}/^{238}\text{U}$ activity ratios ranged from 0.003 to 0.0085. This indicates that the ^{238}U is either depleted or is located far from the probe (i.e., is highly attenuated).

^{232}Th levels are depressed (by up to slightly more than a factor of 2) in the 5.5-9 ft region, essentially the same region where the ^{238}U level is elevated.

^{40}K levels were elevated (up to more than a factor of 2 above normal levels) in the 5.5-6.5 ft region.

Neither ^{239}Pu nor ^{241}Am nor ^{237}Np were detected by GTS Duratek.

DU-4

GTS Duratek detected ^{241}Am at the 4 ft level, in the 5-6 ft region, in the 7-9 ft region, and at the 10 ft level. The ^{241}Am concentration peaked in the 6-8 ft region (reaching a peak value of 128 nCi/g at the 7.5 ft level).

No ^{238}U (other than natural uranium), ^{235}U , ^{239}Pu , or ^{233}Pa were detected by GTS Duratek.

^{232}Th and ^{40}K levels were normal at all levels.

Review of the spectrum obtained at the 7.5 ft level, the level where the reported ^{241}Am concentration peaked, indicated a small 584 keV peak (probably from the (alpha, n) reaction on fluorine) but no 1274 keV peak. There was a hint of a 352 keV peak, possibly from the (alpha,n) reaction on ^{18}O .

DU-5

Elevated levels of ^{238}U were seen in the 6-8 ft region (peaking at 97 pCi/g at the 7.5 ft level). ^{235}U was not seen, indicating that the uranium was either depleted or was located far from the probe (i.e., was highly attenuated).

^{232}Th activity was depressed (up to about a factor of 2) in the 6.5-8 ft region.

^{40}K activity was slightly depressed (less than 50%) in the 6.5-7.5 ft region.

No ^{235}U , ^{239}Pu , ^{241}Am , or ^{233}Pa were seen by GTS Duratek.

DU-6

Elevated levels of ^{238}U were seen at the 1.13, 3, 4.5, and 16 ft levels and in the 6.5-10 ft region. Peak concentrations occurred in the 7.5-9.5 ft region (peaking at 40 and 45 pCi/g at 8.5 and 7.5 ft levels, respectively). No ^{235}U was detected, indicating that the uranium was either depleted or was natural (with its daughters removed) but located far from the probe (i.e., was highly attenuated).

662 keV gamma ray was detected by GTS Duratek at 8.5 ft level and in the 3-4 ft and 6-7 ft regions. My analysis indicates a definite 662 keV peak only at the 3.5 ft level. At the 3.5 ft level there is also a slight hint of a 722 keV peak, indicating that the 662 keV gamma ray is probably from ^{241}Am . It is stretching to detect a 662 keV peak at the other locations.

^{232}Th activity showed a depression (up to more than a factor of 2) in the 6-10.5 ft region.

^{40}K activity exhibited elevated levels in the 8.5-9.5 ft region (up to about a factor of almost 2) and depressed levels (up to in the 6.5-7.5 ft region).

No ^{235}U , ^{239}Pu , ^{241}Am , nor ^{233}Pa were seen by GTS Duratek.

DU-7

^{239}Pu was seen by GTS Duratek in the 7.5-8.5 ft region, at levels from 37 to 64 nCi/g.

^{241}Am was seen by GTS Duratek at the 4.5 ft level, 6 ft level, 7-8.5 ft region, and 10.5 ft level. The concentration in the 7-8.5 ft region varied from 20 to 41 nCi/g.

$^{239}\text{Pu}/^{241}\text{Am}$ ratios were 1.3, 1.8, and 1.9 at the 7.5, 8, and 8.5 ft levels, respectively. These ratios are lower than the value of 6.7 which is what is expected from 30-year-old weapons-grade plutonium with no added ^{241}Am . The ratios indicate that 72-81% of the ^{241}Am did not come from the decay of ^{241}Pu but rather from an additional source of separated ^{241}Am .

^{232}Th concentrations exhibited an increase (about a factor of 2-3) in the 7-8.5 ft region. Review of the spectra indicated that the 911 keV and 969 keV gamma-ray peaks increased proportionately with the 583 keV and 2614 keV peaks. Therefore, in this case, the ^{232}Th concentration actually exhibited an increase (as opposed to no increase in the ^{232}Th but an increase in the ^{228}Th as seen in DU-2).

No ^{238}U (other than natural U), ^{235}U , or ^{233}Pa were seen by GTS Duratek.

Review of the spectrum obtained at the 7.5 ft level, the level where the reported ^{241}Am concentration peaked, indicated a small 583 keV peak (possibly from the (alpha,n) reaction on fluorine) and a very small 352 keV peak (possibly due to the (alpha,n) reaction on ^{18}O).

DU-8

^{239}Pu found at depths between 12 and 16 ft. Peaked at 14.5-15 ft (4944 nCi/g at 14.5 ft level). If GTS Duratek used only the 414 keV gamma ray as a measure for ^{239}Pu , then the reported ^{239}Pu concentrations are biased high due to interference from the 416 keV gamma ray from ^{233}Pa . If this is the case, then 48%, 71%, 86%, 80%, 60%, and essentially all of the ^{239}Pu reported at 13.5 ft, 14 ft, 14.5 ft, 15 ft, 15.5 ft, and 16 ft, respectively, is due to ^{233}Pa . Hence the ^{239}Pu concentrations really are 24 nCi/g, 175 nCi/g, 692 nCi/g, 357 nCi/g, 50 nCi/g, and below LLD at 13.5 ft, 14 ft, 14.4 ft, 15 ft, 15.5 ft, and 16 ft, respectively.

^{233}Pa (i.e., ^{237}Np) found at depths between 13 and 16 ft. It peaked at 14.5-15 ft (4881 pCi/g at 14.5 ft level). It seems to be associated with the ^{239}Pu , its activity tracked the ^{239}Pu activity. Using GTS Duratek's reported ^{239}Pu concentrations, $^{239}\text{Pu}/^{237}\text{Np}$ activity ratios were in the 1.0E03-1.6E03 range for depths of 13.5-15.5 ft. This ratio is much lower (by orders of magnitude) than the ratio (1.107E06) that would be expected if the ^{237}Np resulted from the decay of ^{241}Pu . The ratios indicate that 0.3% of the ^{237}Np came from the decay of ^{241}Pu . However, using our corrected ^{239}Pu concentrations, $^{239}\text{Pu}/^{237}\text{Np}$ activity ratios would be in the 1.4E02-8.3E02 range. These ratios indicate that less than 0.1% of the ^{237}Np came from the decay of ^{241}Pu .

GTS Duratek did not observe any ^{241}Am in the spectra. This is strange because 30-year-old weapons-grade plutonium should have a $^{239}\text{Pu}/^{241}\text{Am}$ ratio of about 6.7. Hence, ^{241}Am concentrations from 1.3 to 738 nCi/g should have been present. Since I would expect the GTS system to have a ^{241}Am detection limit of about 5 nCi/g, we should have seen ^{241}Am at 5 of the 8 locations where ^{239}Pu was seen.

I reviewed the spectrum taken where the indicated ^{239}Pu and ^{237}Np concentrations were a maximum. I performed a quick review of the spectrum taken at the 14.5 ft level and found no 208 keV gamma. The 335 keV line would be masked by the intense 341 keV gamma from ^{233}Pa . I saw a small 662 keV peak and a small 722 keV peak. Therefore, some ^{241}Am is actually present. The 369 keV gamma would be masked by the 375 keV gamma from ^{239}Pu . Nevertheless, the amount of ^{241}Am present is small compared to the amount of ^{233}Pa present. Much more ^{241}Am would be expected to be seen if the ^{237}Np detected had resulted from the decay of ^{241}Am . Therefore, there is a source of separated ^{237}Np .

Elevated levels of ^{232}Th were found at depths of 13.5-15.5 ft (peaked at 14-15 ft, concentration at 14.5 ft was 7.85 pCi/g) and at 7.5-9 ft. Normal soil above and below the waste was in the 1.1-1.5 pCi/g range. Depressed levels (down to about 0.6-0.7 pCi/g) were found in the 12-12.5 ft level and the 6-6.5 ft level.

Would we expect to have any separated ^{232}Th in the Rocky Flats waste? A review of the spectra indicated that the reported ^{232}Th increase in both the 13.5-15.5 ft region and 7.5-9 ft region was due to ^{228}Th (conclusion based on lack of increase of 911 keV and 969 keV peak intensities as the 583 keV and 2614 keV peak intensities increased).

GTS Duratek reported seeing ^{137}Cs in the 5.5-6.5 ft region, in the 7.5-8.5 ft region, at the 11 ft level, and in the 13-15.5 ft region. As mentioned above, the 662 keV peak at the 14.5 ft level is due to ^{241}Am . I reviewed the spectrum obtained at the 11 ft level and found no evidence at all of a peak at 662 keV. I saw a 662 keV and a 722 keV gamma in the spectrum taken at the 156-ft level. Therefore, I suspect that the other reported values for ^{137}Cs are either due to ^{241}Am or are not really present (as is the case for the 11 ft level).

Elevated levels of ^{238}U were found at depths of 11-15.5 ft and 7.5-8.5 ft. The largest peak (469 pCi/g) was found at 12-12.5 ft, and smaller peaks were found at 14.5-15 ft (92 pCi/g) and 7.5 ft (45 pCi/g). ^{235}U was detected only at the 12-13 ft level (peaking at 17.5 pCi/g at 12.5 ft).

The $^{235}\text{U}/^{238}\text{U}$ activity ratio at the 12-12.5 ft depth was 0.03. This might indicate natural U ($^{235}\text{U}/^{238}\text{U}$ activity ratio of natural U is 0.046) or enriched U at a distance (i.e., highly attenuated). ^{235}U was not seen at other depths, although it should have been seen if it was natural or enriched U, unless it was located far from the probe (i.e., highly attenuated).

Elevated levels of natural U (determined from the ^{214}Pb and ^{214}Bi activities) were found at the 7.5-8.5 ft levels. Since the natural U daughters were not seen above normal levels elsewhere where elevated levels of ^{238}U were seen, the ^{238}U probably in those regions is either enriched U or natural U which had been separated from its daughters.

^{40}K was depressed (by about a factor of 2) in the 12-13.5 ft region and in the 7.5-8.5 ft region. It was elevated. It was elevated in the 5-7 ft region, peaking (almost a factor of 3 above normal levels) at 6.5 ft depth.

741-2

GTS Duratek detected ^{239}Pu in the 9-13 ft region (peaking at approximately 2000 nCi/g at the 10 and 10.5 ft levels). If GTS Duratek used only the 414 keV gamma ray to measure ^{239}Pu , then the reported ^{239}Pu concentrations would be biased high by about 5-12% in the 9-10.5 ft region and about 32-44% in the 11-12.5 ft region. The true ^{239}Pu concentrations would be about 66 nCi/g, 746 nCi/g, 1815 nCi/g, 1861 nCi/g, 928 nCi/g, 916 nCi/g, 294 nCi/g, and 47 nCi/g at the 9, 9.5, 10, 10.5, 11, 11.5, 12, and 12.5 ft levels, respectively.

^{233}Pa was seen by GTS Duratek in the 9-17 ft region. Values peaked at the 11 and 11.5 ft levels at 378 and 422 pCi/g, respectively. It peaked at a level about 1 ft below where the ^{239}Pu peaked.

^{241}Am was seen by GTS Duratek at the 0 ft level, at the 1.5 ft level, at the 5.63 ft level, and in the 8-17.51 ft region. It peaked at the 11 and 11.5 ft levels at values of 12,422 and 13,106 nCi/g, respectively.

Based on the GTS Duratek reported ^{239}Pu concentrations, the $^{239}\text{Pu}/^{241}\text{Am}$ ratios ranged from 0.23 to 0.32 in the 9-10.5 ft region, dropped to about 0.1 at 11 and 11.5 ft and then to 0.072, 0.042, and 0.034 at 12, 12.5, and 13 ft, respectively. These ratios are well below the value of 6.7 that is expected from 30-year-old weapons-grade plutonium with no added ^{241}Am . The ratios indicate that in the 9-10.5 ft region, only 3-5% of the ^{241}Am came from the decay of ^{241}Pu . In the other regions, the percentage was about 1%. Therefore, almost all of the ^{241}Am seen is due to additional, separated ^{241}Am . If our corrected ^{239}Pu

concentrations are used, then the $^{239}\text{Pu}/^{241}\text{Am}$ ratios would be lower and the fraction of the ^{241}Am coming from the decay of ^{241}Pu correspondingly lower also.

Based on the GTS Duratek reported ^{239}Pu concentrations, the $^{239}\text{Pu}/^{237}\text{Np}$ ratios decreased with depth throughout the 9-13 ft region, ranging from $1.5\text{E}04$ to $1.8\text{E}03$. These ratios are much lower than the ratio expected (i.e., $1.107\text{E}06$) from 30-year-old weapons-grade plutonium. These ratios indicate that the fraction of the ^{237}Np that came from the decay of ^{241}Pu decreased in this region from about 1.4% to 0.2%. If our corrected ^{239}Pu concentrations are used, then the $^{239}\text{Pu}/^{237}\text{Np}$ ratios would be lower and the fraction of the ^{237}Np due to the decay of ^{241}Pu correspondingly lower also.

The $^{241}\text{Am}/^{237}\text{Np}$ ratio was fairly constant in the 9.5-12 ft region at a value of about $3\text{E}04$. This is about a factor of 5 higher than the ration would be if all the ^{237}Np came from the decay of ^{241}Pu through ^{241}Am . The ration was higher ($4\text{E}04$ to $6\text{E}04$) at most other locations, but still well below what it would be if all the ^{237}Np came from the decay of ^{241}Pu through ^{241}Am .

$^{241}\text{Am}/^{237}\text{Np}$ ratios were $5.97\text{E}04$ at 9 ft, $3.11\text{E}04$ - $3.41\text{E}04$ in the 9.5-12 ft region, $4.16\text{E}04$ at 12.5 ft, $5.61\text{E}04$ at 13 ft, $6.39\text{E}04$ at 13.5 ft, $5.89\text{E}04$ at 14 ft, $3.68\text{E}04$ at 14.5 ft, $2.64\text{E}04$ at 15 ft, $4.41\text{E}04$ at 15.5 ft, $5.89\text{E}04$ at 16 ft, $3.41\text{E}04$ at 16.5 ft, and $3.27\text{E}04$ at 17 ft. These are lower than the expected ratio of $1.005\text{E}05$ that would be expected from 30-year-old ^{241}Am . These ratios indicate that about 41-69% of the ^{237}Np did not come from the decay of ^{241}Am , but is an additional source of separated ^{237}Np .

A 1274 keV gamma was seen by GTS Duratek in the 8.5-14.5 ft region (peaking at a value of 14.0 and 14.6 cps at the 10 and 10.5 ft levels, respectively) and at the 16 ft level. This gamma ray is due to the (alpha,p) reaction on fluorine. Also seen in the 8-15 ft region (peaking at a value of 5.6 and 5.2 cps at the 10 and 10.5 ft levels, respectively) was the 2223 keV gamma ray from the (n,gamma) reaction on hydrogen. Both these gamma rays indicate a presence of neutrons, primarily from ^{241}Am . Both these gamma rays had peak intensities about 1 ft above where the ^{241}Am intensity peaked.

Review of some of the spectra taken from the 8.5-14.5 ft region indicated the presence of a 583 keV peak from the (alpha,n) reaction on fluorine.

^{232}Th exhibited enhanced concentrations in the 8.5-17 ft region, peaking at 55 and 58 pCi/g at the 11.5 and 12 ft levels, respectively (about a factor of almost 40 above the concentration seen in normal INEEL soil). Review of the spectra indicates that the reported enhanced concentrations of ^{232}Th are actually due to ^{228}Th .

GTS Duratek was unable to detect natural uranium in the 9.5-12 ft region, probably due to the high levels of ^{241}Am seen in that region.

^{40}K activity exhibited a depression (by up to about a factor of 2) in the 10.5-11.5 ft region.

Neither ^{238}U (other than natural uranium based on ^{214}Bi and ^{214}Pb daughters) nor ^{235}U was reported by GTS Duratek.

741-3

^{238}U was detected in the 17-18.68 ft region (at 21-30 pCi/g) and sporadically at other locations. The presence of ^{235}U was not reported.

GTS Duratek saw ^{239}Pu in the 8.5-12.5 ft region, at the 14 ft level, and in the 17-18.68 ft region. The concentration peaked twice in the 9-10.5 ft region, at values ranging from 672 nCi/g to 782 nCi/g between 9 and 10.5 ft and at values from 488 to 508 nCi/g between 11.5 and 12 ft. Another peak was seen in the 18-18.68 ft region, reaching values of 133 and 172 nCi/g at the 18.5 and 18.68 ft levels, respectively. Since 18.68 ft is as deep as was logged, the depth to which the ^{239}Pu extends is unknown as is the location and concentration of the peak.

If GTS Duratek used only the 414 keV gamma ray to measure ^{239}Pu , then the reported concentrations would be significantly biased high (about 16-32%) for the 8.5-12.5 ft region. The values reported for the 18-18.68 ft region would be biased high by 2% or less. The corrected ^{239}Pu concentrations would be about 105 nCi/g, 594 nCi/g, 541 nCi/g, 599 nCi/g, 525 nCi/g, 319 nCi/g, 406 nCi/g, 356 nCi/g, and 179 nCi/g at the 8.5 ft, 9 ft, 9.5 ft, 10 ft, 10.5 ft, 11 ft, 11.5 ft, 12 ft, and 12.5 ft levels, respectively.

^{241}Am was detected by GTS Duratek in the 0.5-1 ft region; at the 2, 4, and 6 ft levels, in the 7.5-14.5 ft region; and at the 15, 17, and 18.68 ft levels. Two peaks were observed in the 7.5-14.5 ft region (7938 nCi/g at 9.5 ft and 4822 nCi/g at 12 ft). These locations are approximately where the ^{239}Pu exhibited its peak concentrations.

Based on the GTS Duratek reported ^{239}Pu concentrations, the $^{239}\text{Pu}/^{241}\text{Am}$ ratios were on the order of 0.1 at all locations except for the 17 and 18.68 ft levels, where they were 1.3 and 8.5, respectively. This indicates that all the ^{241}Am seen except at the 18.68 ft level is due to excess ^{241}Am , but at the 18.68 ft level it is due to ^{241}Am from the decay of ^{241}Pu .

^{233}Pa was seen in the 8.5-14 ft and 18-18.68 ft regions. As with ^{239}Pu and ^{241}Am , two peaks were seen (244 pCi/g at 9.5 ft and 127 pCi/g at 12 ft). These locations are approximately where the other radionuclides exhibited peak concentrations.

The $^{241}\text{Am}/^{233}\text{Pa}$ ratio was about 3.5E04 in the 9-12.5 ft region but higher (about 4.5E04 to 8.7E04) in the 13-14 ft region. 3.5E04 is about a factor of 3 lower than the expected ratio if all the ^{237}Np came from the decay of ^{241}Am . The ratios are lower than the ratio (1.005E05) expected from 30-year-old weapons-grade plutonium. These ratios indicate that about 13-65% of the ^{237}Np came from the decay of ^{241}Am .

Based on the GTS Duratek reported ^{239}Pu concentrations, the $^{239}\text{Pu}/^{237}\text{Np}$ ratios were in the 3.3E03-5.5E03 in the 8.5-12.5 ft region, 7.2E02 at the 14 ft level, and 6.6E04-1.3E05 in the 18-18.68 ft region. These ratios are much lower than the ratio expected (1.107E06) from 30-year-old weapons-grade plutonium. These ratios indicate that in the 8.5-12.5 ft region and at the 14 ft level, less than 0.5% of the observed ^{237}Np came from the decay of ^{241}Pu . For the 18-18.68 ft level, 60-100% of the ^{237}Np came from the decay of ^{239}Pu .

^{40}K concentration showed slightly higher values at lower depths and a slight deficiency in the 13-13.5 ft region.

^{232}Th exhibited elevated concentrations in the 8.5-14 ft region, peaking at 10 pCi/g at 11.5 and 12 ft. Review of the spectra indicates that these reported elevated concentrations are actually due to ^{228}Th .

Natural uranium showed a decrease of about a factor of 2-3 at levels in the 8-11.5 ft region where values were obtained (values were not obtained at every level).

Hydrogen capture gamma rays were seen in the 7-15 ft region, peaking at slightly over 5 cps at 9.5-10 ft and at 11.5 ft. 1274 keV gamma rays from the (alpha,p) reaction on fluorine were seen in the 7-14.5 ft region, peaking at about 8 cps at the 9.5 ft level and at about 16 cps at 11.5-12 ft. 1778 keV gamma rays (probably from the (n,p) reaction on silicon) were seen in the 7.5-12.5 ft region, peaking at about 0.7 cps at the 10.5 ft level. All of these reaction gamma rays indicate the presence of a neutron flux (both fast and thermal), which is mainly due to the neutrons from (alpha,n) reactions caused by the alphas from ^{241}Am .

Review of spectra obtained from the 9-12 ft region indicated the presence of a fairly large 1274 keV peak and a small 583 keV peak, both from alpha-induced reactions on fluorine.

741-4

^{239}Pu was seen by GTS Duratek in the 8.5-13 ft region (peaking at 1065 nCi/g at 9.5 ft and 478 at 12 ft). If GTS Duratek used only the 414 keV gamma ray to measure ^{239}Pu , then the reported values are biased high (by 5-19%) due to interference from the 416 keV gamma ray from ^{233}Pa . The corrected ^{239}Pu concentrations are 13.5 nCi/g, 314 nCi/g, 894 nCi/g, 735 nCi/g, 657 nCi/g, 187 nCi/g, 257 nCi/g, 429 nCi/g, 136 nCi/g for the 8.5, 9, 9.5, 10, 10.5, 11, 11.5, 12, and 12.5 ft levels, respectively.

^{241}Am was seen by GTS Duratek in the 8-14.5 ft region, 17.7-18 ft region, 20 ft level, and the 22.5 ft level. The 17.7-18 ft region, 20 ft level, and the 22.5 ft level. The errors are large for the results in all but the 8.5-14 ft region. Two peaks in concentration were seen, 5509 nCi/g at 9.5 ft and about 2300 at 11.5-12 ft.

$^{239}\text{Pu}/^{241}\text{Am}$ ratios were generally in the 0.1 to 0.2 range. This is much lower than the expected ratio (6.7) for 30-year-old weapons-grade plutonium. The ratios indicate that 97-95.5% of the ^{241}Am did not come from the decay of ^{241}Pu but from an additional, separated source of ^{241}Am .

^{233}Pa was detected by GTS Duratek in the 8.5-12.5 ft region (peaking at 172 pCi/g at 9.5 ft).

$^{241}\text{Am}/^{233}\text{Pa}$ ratio ranged from 3.2E04 to 7.0E04, which is much lower than the value of 1.005E05 which would be expected if all the ^{237}Np came from the decay of ^{241}Am . These ratios indicate that 30-68% of the ^{237}Np did not come from the decay of ^{241}Am , but from an additional, separated source of ^{237}Np .

Using the GTS Duratek reported ^{239}Pu concentrations, the $^{239}\text{Pu}/^{237}\text{Np}$ ratios were 3.0E03 at the 8.5 ft level, 5.7E03-8.6E03 in the 9-12 ft region, and 1.61E04 at the 12.5 ft level. These ratios are much lower than the ratio (1.107E06) expected from 30-year-old weapons-grade plutonium. This indicates that less than 1% of the ^{237}Np in the 8.5-12 ft region and about 1.5% of the ^{237}Np at the 12.5 ft level is due to the decay of ^{241}Pu .

GTS Duratek reported ^{137}Cs in the 6-6.5 ft (very low concentrations, probably not statistically significant) and 13-20 ft regions (peaking at 112 pCi/g at 14.5 ft and 140 pCi/g at 16-16.5 ft). I checked the spectrum taken at 14.5 ft, and the peak is definitely due to ^{137}Cs . It is a very large peak, and no hint of a 722 keV peak is seen.

Hydrogen capture gamma rays were seen in the 8-15 ft region (peaking at 2.5-2.7 cps at 9.5-10.5 ft). 1274 keV gamma rays (from the (alpha,p) reaction on fluorine) were seen in the 8-14.5 ft region (peaking at 10.4 cps at 9.5 ft, approximately where the hydrogen capture gamma rays peaked). The presence of these gamma rays indicates a neutron flux (both thermal and fast), probably due to the ^{241}Am .

Review of the spectra obtained from the 9-12 ft region indicated the presence of a 1274 keV and a small 583 keV peak, both from alpha-induced reactions on fluorine.

^{40}K exhibited a slight depression in the 10.5-11.5 ft region.

^{232}Th exhibited an enhance concentration in the 9-13.5 ft region, peaking at 11 pCi/g at 10.5-11 ft. Review of the spectra indicates that these reported enhanced concentrations are actually due to ^{228}Th .

Neither ^{238}U (other than natural uranium detected from its ^{214}Bi and ^{214}Pb daughters) nor ^{235}U was reported by GTS Duratek.

741-6

^{238}U was seen in the 3.5-4 ft region (at levels of 3-4 pCi/g), in the 10.5-16.5 ft region (at levels of 11.8-681 pCi/g, peaking at 13.5-14.5 ft), and at the 17.44 ft level (at 5 pCi/g). ^{235}U was detected in the 14.5-17.44 ft region (peaking at 84 pCi/g at 15.5 ft).

The $^{235}\text{U}/^{238}\text{U}$ activity ratio was 0.0043 at 14.5 ft, 0.097 at 15 ft, 0.98 at 15.5 ft, 2.17 at 16 ft, 1.43 at 16.5 ft, and 1.44 at 17.44 ft. This indicated the presence of enriched- or highly enriched uranium at about the 16-ft level and the presence of depleted uranium in the 10.5-14.5 ft region.

Review of the spectra indicated that the 144 keV gamma ray from the decay of ^{235}U is seen in the spectra obtained at the 15.5 and 16-ft levels. The intensity of this gamma ray is highest at the 15.5 ft level, and the 186 keV/144 keV peak intensity ratios are similar to what would be expected for ^{235}U measured through the $\frac{1}{2}$ "-thick probe wall by the GTS Duratek detector. This indicates that at this level the ^{235}U is relatively close to the probe, i.e., there is essentially no intervening soil between the ^{235}U and the probe.

GTS Duratek reported ^{239}Pu at levels of 15.7-1504 nCi/g in the 9.5-12 ft region (peaking at the 10.5 ft level). Corrections due to interference from the 416 keV ^{233}Pa gamma ray (if GTS Duratek used only the 414 keV line for determining ^{239}Pu) would be on the order of 4% or less.

^{241}Am was seen in the 6.5-7 ft region (at levels of about 7-15 nCi/g) and in the 9-12.5 ft region (peaking at the 10.5 ft level at 2386 nCi/g).

^{233}Pa was seen in the 10-11.5 ft region (peaking at the 10.5 ft level at 72 pCi/g).

$^{239}\text{Pu}/^{237}\text{Np}$ ratios ranged from 1.73E04 to 2.51E04. These ratios are much lower than the ratio expected (1.107E06) from 30-year-old weapons-grade plutonium. The ratios indicate that only about 1-2% of the ^{237}Np is due to the decay of ^{241}Pu .

$^{241}\text{Am}/^{237}\text{Np}$ ratios were 5.14E04, 3.31E04, 3.85E04, and 9.23E04 at the 10, 10.5, 11, and 11.5 ft levels, respectively. Except for the 11.5 ft level, these ratios are lower than the expected ratio (1.005E5) for 30-year-old ^{241}Am . The ratios in the 10-11 ft region indicate that about 49-67% of the ^{237}Np is not due to the decay of ^{241}Am , but from an additional source of separated ^{237}Np .

$^{239}\text{Pu}/^{241}\text{Am}$ ratios are 0.29, 0.49, 0.63, 0.53, 0.19, 1.07 at the 9.5, 10, 10.5, 11, 11.5, and 12 ft levels. These ratios are much lower than the ratio expected (6.7) for 30-year-old weapons-grade plutonium. The ratios indicate that 84-97% of the ^{241}Am is not from the decay of ^{241}Pu but from an additional source of separated ^{241}Am .

Review of the spectrum obtained from the 10.5 ft level indicated the presence of small 583 keV and 1274 keV peaks, from alpha-induced reactions on fluorine.

^{40}K behaved approximately normally throughout the 0.5-13.5 ft region (although there was a slight increase in concentration in the 67-7.5 ft region). The ^{40}K concentration began to decrease at 14 ft, dropping to almost $\frac{1}{2}$ its normal value by the time a 17-ft depth was reached.

^{232}Th exhibited an increase in the 9.5-11.5 ft region (peaking at 5.86 pCi/g at 10.5 ft). Review of the spectra indicates that these reported increased concentrations are actually due to ^{228}Th . Its concentration also dropped below normal in the 17-17.44 ft region.

Natural U exhibited a lower-than-normal concentration at 11.5 ft and was not detected in the 10-11 ft region.

741-8

^{239}Pu was detected by GTS Duratek in the 7-16 ft region, peaking at two locations, 8058 nCi/g at 8 ft and 230-240 pCi/g at 12.5-13.5 ft. Corrections due to interference from the 416 keV gamma ray from ^{233}Pa (if GTS Duratek used on the 414 keV gamma ray to measure ^{239}Pu) would be about 6% or less.

^{241}Am was seen at the 4 level, in the 6-13.82 ft region, and in the 15-16 ft region. Peaks of 8874 nCi/g and 174 nCi/g were observed at 8 ft and 12.5 ft, respectively.

^{233}Pa was seen in the 7-13.5 ft region, peaking at 311 pCi/g at 8.5 ft.

^{239}Pu , ^{241}Am , and ^{233}Pa all peaked at 8-8.5 ft. ^{239}Pu peaked again at 12.5-13.5 ft; ^{241}Am and ^{233}Pa peaked at a bit higher level (12.5 ft)

$^{239}\text{Pu}/^{237}\text{Np}$ ratios varied from 1.31E04 to 3.47E04 for the 7-12.5 ft region, rose to 6.18E04 at the 13 ft level, rose to 1.328E05-1.608E05 at 13.5-14.5, and dropped to 3.21E04 at 15.5 ft. These ratios are much lower than the ratio expected (1.107E06) for 30-year-old weapons-grade plutonium. The ratios indicate that in the 13.5-14.5 ft region, 85-88% of the ^{237}Np is not from the decay of ^{241}Pu , at 13 ft 94% of the ^{237}Np is not from the decay of ^{241}Pu , and in the 7-12.5 ft region 97-99% of the ^{237}Np is not from the decay of ^{241}Pu . Most of the ^{237}Np , therefore, is due to an additional source of separated ^{237}Np .

$^{241}\text{Am}/^{237}\text{Np}$ ratios were in the 1.77E04 – 4.83E04 range. These values are lower than the ratio expected (1.005E05) from 30-year-old ^{241}Am . The ratios indicate that about 52-82% of the ^{237}Np is not from the decay of ^{241}Am but from an additional source of separated ^{241}Am .

$^{239}\text{Pu}/^{241}\text{Am}$ ratios varied from 0.27 to 4.27. The ratio was 0.27 at 7 ft, 0.49 – 1.005 in the 7.5-12 ft region, 1.38 at 12.5 ft, 3.49-3.73 in the 13-13.82 ft region (with the exception of an anomalous value of 0.95 at 15 ft), and 1.77 at 16 ft. These values are lower than the expected ratio (6.7) for 30-year-old weapons-grade plutonium. The ratios indicate that the fraction of ^{241}Am not from the decay of ^{241}Pu is about 96% at 7 ft, 85-93% in the 7.5-12 ft region, 79% at 12.5 ft, 44-48% in the 13-13.82 ft region, and 74% at 16 ft.

1274 keV gamma rays from the (alpha,p) reaction on fluorine due to alpha from ^{241}Am were seen in the 6.5-13.5 ft region. Their intensity peaked at 8-8.5 ft (at about 20 cps). Review of the spectra obtained from this region indicated the presence of a 583 keV peak (of lower intensity than the 1274 keV peak), from the (alpha,n) reaction on fluorine.

2223 keV capture gamma rays from (n,gamma) reaction on hydrogen due to neutrons from ^{241}Am reactions were seen in the 6.5-10.5 ft region (peaking at 4.1 cps at the 8 ft level).

^{232}Th exhibited enhanced concentrations in the 6.5-9.5 ft region (peaking at 11-13 pCi/g at 8-8.5 ft). Concentrations above and below this region were normal (i.e., about 1.1-1.4 pCi/g). Review of the spectra indicates that these reported increased concentrations are actually due to ^{228}Th .

The natural uranium concentrations did not exhibit any trend. However, natural uranium was not detected in the 7-9 ft region.

^{40}K concentrations exhibited a depression (less than a factor of 2) in the 12.5-13.82 ft region.

Neither ^{238}U (other than natural uranium detected from its ^{214}Bi and ^{214}Pb daughters) nor ^{235}U was reported by GTS Duratek.

741-9

^{238}U was detected in the 8.91-13.75 ft region at concentrations ranging from about 20 to 267 pCi/g. Two distinct peaks were observed, 267 pCi/g at 10.5 ft and 255 pCi/g at 13 ft.

^{235}U was detected in the 10-13.75 ft region (except at the 12 ft level) at concentrations ranging from 1.5 to 28 pCi/g. Two distinct peaks were observed, 15-18.5 pCi/g at 10/5-11 ft and 29 pCi/g at 13-13.75 ft.

$^{235}\text{U}/^{238}\text{U}$ activity ratios were 0.053, 0.069, 0.076, and 0.015 at 10 ft, 10.5 ft, 11 ft, and 11.5 ft, respectively, and 0.045, 0.11, 0.20, and 0.32 at 12.5 ft, 13 ft, 13.5 ft, and 13.75 ft, respectively. These ratios indicate a source of enriched- or highly enriched uranium at 10.5-11 ft and another source or below 13.75 ft.

A review of the spectra indicated that the 144 keV gamma ray from ^{235}U was seen in the 13-13.75 ft region. The peaks were very small, but on the order of what would be expected for the intensities of the 186 keV peaks seen. Therefore, there is little to no shielding material (e.g., soil) between the ^{235}U and the probe.

No ^{239}Pu , ^{241}Am , or ^{233}Pa were reported.

GTRS Duratek reported seeing ^{137}Cs in the 10-11.5 ft region and in the 13-13.75 ft region. Visual inspection of the spectra indicates the following:

<u>Depth</u>	<u>Comments</u>
10 ft	very small 662 keV peak with no indication of a 722 keV peak (although the 722 keV peak would be expected to be too small to be seen if the 662 keV peak was from ^{241}Am)
10.5 ft	small 662 keV peak with no 722 keV peak (although the 722 keV peak would be expected to be small and very hard to detect if the 662 keV peak was from ^{241}Am)
11 ft	definite 662 keV peak with no 722 keV peak (at least a hint of a 722 keV peak would be expected if the 663 keV peak was from ^{241}Am)
11.5 ft	maybe a very slight hint of a 662 keV peak, but hard to tell
12 ft	no indication whatsoever of a 662 keV peak

12.5 ft no indication of a 662 keV peak

13 ft maybe a very slight hint of a 662 keV peak

13.5 ft very small 662 keV peak with no indication of a 722 keV peak
(although the 722 keV peak would be expected to be too small to
be seen if the 662 keV peak was from ^{224}Am)

13.75 ft very small 662 keV peak with no indication of a 722 keV peak
(although the 722 keV peak would be expected to be too small to
be seen if the 662 keV peak was from ^{241}Am).

My conclusion is that ^{137}Cs may be present at the 11-ft level, but at the other levels, one cannot rule out the 662 keV peak from being from ^{241}Am . Re-logging with longer count times will be required to confirm the presence of ^{137}Cs .

GTS Duratek reported ^{60}Co in the 10-11.5 ft region and in the 13.5-13.75 ft region. Visual inspection of the spectra indicates the following:

<u>Depth</u>	<u>Comment</u>
10 ft	maybe a hint of 1173 and 1332 keV peaks
10.5 ft	hint of an 1173 keV peak but no 1332 keV peak
11 ft	hint of an 1173 keV peak and maybe something at 1332 keV
11.5 ft	hint of an 1173 keV peak and maybe something at 1332 keV
13.5 ft	nothing at 1173 keV but maybe a hint of a peak at 1332 keV
13.75 ft	very small peak at 1173 keV and a hint of a peak at 1332 keV

My conclusion is that maybe a very small amount of ^{60}Co is present, but re-logging using longer count times is required to confirm the presence of ^{60}Co .

^{232}Th exhibited a definite decrease in concentration (up to about a factor of 2 to 3) in the 12-13.75 ft region.

The natural uranium concentration did not exhibit any definite trend.

^{40}K indicated an increased concentration in the 6-10 ft region and a definite decrease in concentration (up to about a factor of 3 to 4) in the 12.5-13.75 ft region.

Appendix B

J. Giles notes on evaluation of DU and 741 Study Area subcontractor data

Recommendations for OU 7-13/14 from Nuclear Data Analysis

John R. Giles

Revised 12/5/2000

An accelerated data analysis was performed on the most recent logging data from the probeholes placed in the DU and 741 Sludge focus areas in support of the OU 7-13/14 project. After review of the data, it was decided that additional information from the existing probeholes should be gathered prior to making a final recommendation for the placement of additional Type A and the Type B probes. The following are the recommendations and justification for the azimuthal logging:

Azimuthal Logging Recommendations

The azimuthal logging in probeholes associated with the DU study area should focus on the relative radial intensity of the 186-keV gamma-ray from the decay of U-235. This low energy gamma-ray will be attenuated by the shielded portion of the azimuthal detector by approximately 80%, while the 1,001-keV gamma-ray from Pa-234m (U-238 daughter) is attenuated by approximately 54%. As a result, the directional capabilities of the azimuthal tool for U-238 are significantly less than for U-235. The azimuthal logs in probeholes associate with the 741 Sludge study area should focus on the directional orientation of all COCs including Pu-239, Am-241 and Np-237 (Pa-233).

DU Study Area

DU-3 Azimuthal logs should be run for the purpose of identifying the directional orientation of the source of U-235 at a depth of 9.0 ft.

DU-8 Azimuthal logs should be run for the purpose of identifying the directional orientation of the source of U-235 at a depth of 12.5 ft.

Probehole DU-8 may also be of interest for use in evaluating 741 Sludge. There were significant quantities of Pu-239 and Pa-233 (Np-237) identified at a depth interval from 13.5 to 16 ft. The maximum Pu-239 concentration reported by GTS is 4,944 nCi/g, and the maximum Pa-233 concentration reported by GTS is 4,881 pCi/g. These maximum concentrations were reported at a depth of 14.5 ft. The Pu-239 and Pa-233 concentrations peak at a different depth than the U-238 and U-235 peak concentrations, suggesting that there may be two different waste types at two distinct locations near this probehole.

741 Sludge Study Area

741-2 Azimuthal logs should be run for the purpose of identifying the directional orientation of Pu-239, Am-241 and Pa-233 at depths of 10.5 and 11.5 ft.

741-3 Azimuthal logs should be run for the purpose of identifying the directional orientation of Pu-239, Am-241 and Pa-233 at a depth of 9.5 ft.

741-6 Azimuthal logs should be run for the purpose of identifying the directional orientation of Pu-239, Am-241 and Pa-233 at a depth of 10.5 ft.

741-8 Azimuthal logs should be run for the purpose of identifying the directional orientation of Pu-239, Am-241 and Pa-233 at depths of 8.0 and 12.5 ft.

Probehole 741-6 may also be of interest for use in evaluating uranium waste. Enriched uranium was identified at a depth interval from 15.0 to 17.44 ft (bottom of probehole).

Probeholes 741-2, 741-3, 741-6, and 741-8 have contaminants of concern detected at significant concentrations at or very near the bottoms of the probeholes.

Summary of Observations that may Warrant Further Investigation

- Apparent elevated natural thorium concentrations were observed in several of the probeholes in the 741 Sludge study area, indicating a potential source of Th-228 that was not identified in the interim baseline risk assessment. Probehole 741-2 exhibits the highest observed concentrations of natural thorium at a depth of 12.0 ft and a concentration of 58.41 pCi/g. The elevated thorium in probehole 741-2 spans a depth range from approximately 8.0 ft to 17.0 ft. The elevated thorium is also present in probeholes 741-3, 741-6, 741-8, DU-7 and DU-8; however, the elevated thorium in DU-7 has been determined to be natural thorium (Th-232). It is important to note here that the mean background value for natural thorium in INEEL soils is 1.25 pCi/g (Rood et al. 1996).
- Enriched, or highly enriched uranium was identified in probeholes 741-6 and 741-9. These zones were identified at the bottoms of the probeholes, separate from any Am-241 or Np-237. Natural uranium or enriched uranium located far from the probe (see J.W. Mandler's observations and comments).
- Cesium-137 was identified in probehole 741-4 at a depth interval from 13.0 to 20.0 ft, with a maximum concentration of 139.4 pCi/g at a depth of 16.5 ft. It was determined that this is a true source of Cs-137, as discussed in J.W. Mandler's observations.
- Several probeholes in the 741 Sludge study area exhibit concentrations of Np-237 that indicate a source of separated Np-237, that is not associated with the decay of Am-241 originally disposed in the area.

Additional Type A Probe Installation Options

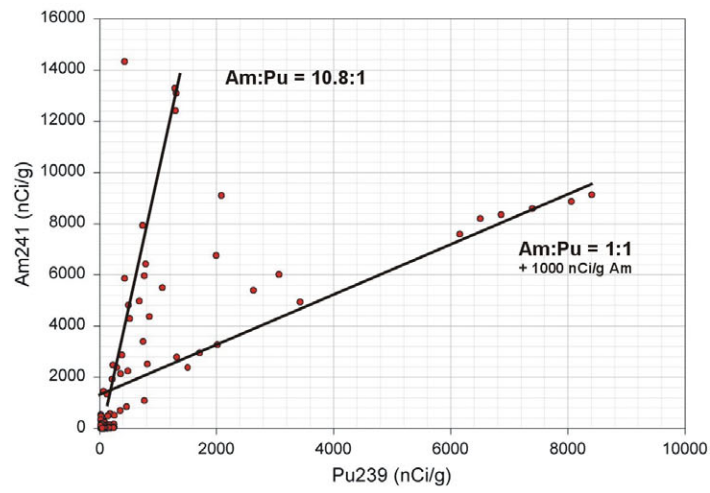
Based on the review and observations of the preliminary logging data provided by GTS Duratek, there are two possible options for the installation of additional Type A probes:

Install the 6 additional Type A probes in a ring, concentric with the probe of interest (i.e. DU-3). The spacing on the Type A probes should be a maximum of 2 ft, however the preferred spacing is 1.5 ft. These additional probes would be logged by GTS, with a detailed data review provided by INEEL personnel. Additionally, recommendations for azimuthal logging in the detailed probehole cluster would be provided. Analysis of general logging data and directional data by INEEL personnel would be provided to assist in the location of Type B probes.

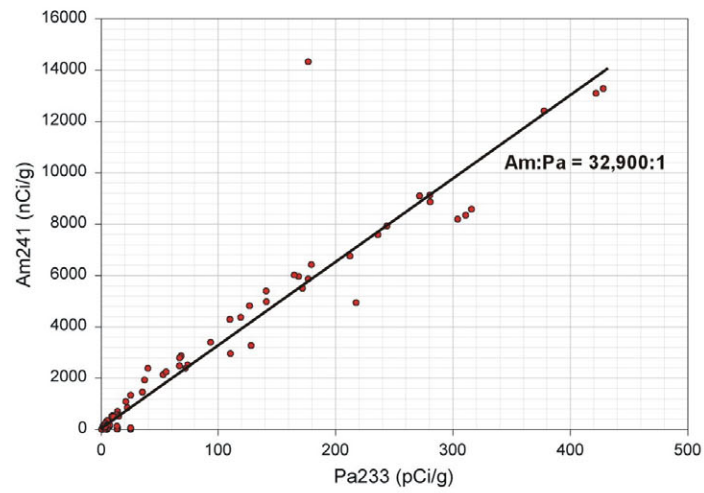
Delay the installation of the additional Type A probes for the detailed probehole cluster until the azimuthal logging tool has been repaired. The azimuthal logging tool should be deployed, as detailed above. Upon analysis of the directional data by GTS and INEEL personnel, recommendations can be made for the installation of additional Type A probes. This method may eliminate installation of excessive probeholes, and minimize cost. After installation and logging of the additional Type A probes, a detailed analysis of the logging data will be performed with recommendations for additional azimuthal logging locations in the new probeholes. All of the data will then be analyzed by INEEL personnel, and recommendations for the location of Type B probes will be provided.

Appendix C
Gamma-ray Ratio Charts

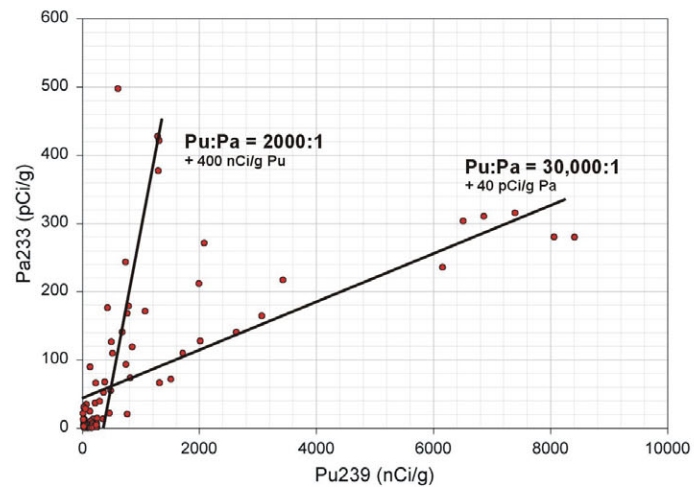
Am/Pu



Am/Pa



Pu/Pa



bmb

cc: Bruce H. Becker, MS 3920
Swen O. Magnuson, MS 2107
T. J. Meyer, MS 3920
Hopi Solomon, M-K
ARDC Files, MS 3922
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